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GETTING OUT OF THE COMMONS TRAP: VARIABLES, PROCESS, AND RESULTS IN FOUR GROUNDWATER BASINS

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ABSTRACT

Jointly-accessible resources used by multiple individuals are often endangered. Indeed, we call the supposedly inevitable destruction of such resources "the tragedy of the commons". Commons problems have been classified with other "social traps" such as the collective action problem and the Prisoner's Dilemma game. Reasoning by analogy and metaphor from these other "traps" has yielded a general prognosis of doom for the commons, escapable only via privatization of the resource or centralized public management.

In fact, alternative organizations of resource use exist, and have led to resource preservation and even to resource enhancement. The question is how, and under what conditions, users of a common resource might collectively coordinate their behavior to avoid impending doom and enhance resource use without resort to either of the forms prescribed in the prevailing literature. Drawing upon the methods of institutional analysis and the experience of actual cases of commons management, this paper presents descriptive and quantitative evidence on: (a) the relevant characteristics of the settings in which resource users operate, (b) the steps taken in a process of resolution of a commons dilemma, and (c) the results obtained thus far by the users of groundwater basins in arid and heavily populated portions of southern California. The likelihood of successful resolution is compared across different settings, and the efficiency and equity of different public-private organizational form mixes are compared, as well.

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A commons (or a common-pool resource) is a resource that is not under the ownership of an individual, to which more than one individual has access, and that generates subtractable yields that are appropriated by the individuals who have access to that resource. Among the several examples of jointly-accessible resources that produce separately appropriable yields are forests, fisheries, grazing lands, surface bodies of water, and groundwater basins. Following the typology of goods presented by Ostrom and Ostrom (1978: 12), common-pool resources exhibit relatively lower feasibility of exclusion than do private goods, and relatively higher subtractability in use than do public goods. This combination, in the absence of some arrangements to control use, renders common-pool resources susceptible to problems of overuse, depletion, and even destruction. When several individuals use a jointly-accessible yet subtractable resource, the resource can be in danger. This is not merely an abstract or theoretical threat — examples of overused, depleted, and destroyed forests, fisheries, grazing lands, surface bodies of water, and groundwater basins exist.

I. The Commons as "Social Trap"

Because the dangers that threaten common-pool resources inhere in their defining characteristics (i.e., multiple

access to the resource, non-ownership, and subtractability of the yield), overuse, depletion, and destruction have been thought to be the inalterable fate of all such resources. Indeed, we have coined the phrase "the tragedy of the commons[11] (G. Hardin, 1968) for their supposedly inevitable destruction. Commons problems have been classed as "social traps" — situations in which individually rational actions produce socially undesirable outcomes — and analyzed together with other "traps". Escapes therefrom have been prescribed together, as well.

A. The Metaphors

The reasoning of Garrett Hardin, asserting that the "inherent logic of the commons remorselessly generates tragedy" (1968: 1244), appeared in print shortly after the publication of Mancur Olson's The Logic of Collective Action. Hardin's article described collective destruction brought on by the uncontrolled, but nonetheless rational, actions of individuals. Olson's book described collective benefits foregone as a result of the uncoerced, rational actions of individuals. The problems presented by the two authors appeared as opposite sides of the same coin: the "tragedy of the commons" was just the "collective action problem" in reverse. Failure to stop the destruction of a valued good — or, put another way, failure to avert a "bad" (Buchanan, 1970) — was essentially the same as failure to produce a valued good. Either case was a "social trap".

The equating of the collective action problem with the "tragedy of the commons" overlooked the fact that Olson was writing about public goods and Hardin about common-pool resources. This was understandable, since Olson defined public goods in terms of the one characteristic they share with common-pool resources, viz., low feasibility of exclusion. And indeed, non-excludability is a key to understanding why individuals might not act to reduce their use of an overused resource. Reduction of use by an individual may improve the conditions of the resource, but the benefits from that reduction cannot be captured by the individual who reduces use. The benefits of reduced use are shared by all users. And, in Olson's analysis of the public goods problem, it is precisely this inability of the individual who considers contributing to the collective benefit to exclude non-contributors from sharing in the gain that generates the predicted failure of collective action. Commons problems thus appeared to be an interesting subset of collective action problems.

Another "social trap" was attracting attention at the time of scholars' interest in the theory of public goods and Olson's collective action problem. Game theory's Prisoner's Dilemma captures in an essential and formal **manner** the problem of collective detriment realized as a result of the pursuit of individual benefit. Independent decision-makers operate in a context where their fates are linked to each

other's choices, much as is the case with multiple users of a jointly-accessible yet subtractable resource.

The set of outcomes of a Prisoner's Dilemma game relate directly to the outcomes obtainable in the use of a commons. There is an individual's best outcome when others exercise restraint while the individual does not, a second-best outcome when all actors exercise restraint, a third-best outcome when all actors do not exercise restraint, and a worst outcome when the individual exercises restraint and other actors do not. If all individuals pursue their best outcomes, all do not exercise restraint, and the joint result of their individual choices is that they realize their third-best outcome rather than their best or second-best. And yet this result is exactly what game theorists predicted for Prisoner's Dilemma situations, which was in accord with the "tragedy of the commons" predictions, as well. Indeed, Dawes and colleagues developed and presented a particular for of N-person Prisoner's Dilemma which they called the "commons dilemma game" (Dawes, 1973; Dawes et al., 1977). Commons problems thus appeared to be an interesting subset of the Prisoner's Dilemma game.

The Prisoner's Dilemma game and the collective action problem were themselves linked as types of "social traps". Russell Hardin observed that the "problem of collective action in social contexts is the Prisoner's Dilemma writ large" (1982: xiii). Thomas Schelling united the collective action problem, the Prisoner's Dilemma, and the commons in

his deservedly widely-read Micromotives and Macrobehavior. Whether social scientists had identified the genus "Social Trap", of which "Collective Action," "Prisoner's Dilemma," and "Tragedy of the Commons[11] were species, or had identified the species "Social Trap" for which these other names were merely colloquial descriptors without distinguishing relevance, was unclear. But it was clear that the three were at least linked, if not outright interchangeable.

B. The Solutions

The logic of the Prisoner's Dilemma, the "logic of collective action," and "the inherent logic of the commons" all lead to one conclusion: individuals will not cooperate in their use of a common resource and indeed will pursue strategies leading to the destruction of that resource. Based on this "social trap" logic, scholars have made recommendations for the organization of resource use that would provide an escape from the commons trap.

These "escapes" involve conversion of the resource from common property to some other form of property. They are based upon a conviction that as long as the commons remains a commons, its "inherent logic" does indeed "inexorably lead to destruction." Because the commons is conceived as identical to a collective action problem in the provision of a public good and to a Prisoner's Dilemma, it is conceived as equally intractable as **these** problems. Only centrally-directed coercion to make people behave responsibly in their interdependent situation (G. Hardin, 1968; Carruthers and

Stoner, 1982), or privatization that eliminates the interdependence itself and divides the commons anew among independent proprietors (T. Anderson, 1983; Welch, 1983; R. Smith, 1981) can avert the destruction of resources and enhance the efficiency and equity of their use. To one group of scholars, only the centralized management of resources as public property could work. To another group of scholars, only the individual ownership of resources as private property could work.

The opposition of these two "solutions'* has led another set of scholars to speculate on their actual validity. Since the advocates of each approach contend for their solution as the only way for resources to be saved, it is clear that both cannot be correct. The question then arises whether in fact either approach can substantiate a claim that it alone can provide for resource preservation and enhancement. Other scholars, who have studied cases of resource management in actual settings across different time periods, resource types, and locations, have found that cases of resource destruction can be found under a variety of forms of organization of resource use, and that cases of resource preservation and enhancement can be found under a variety of forms of organization of resource use (see, for example, E. Ostrom, 1986; Panel on Common Property Resource Management, 1986).

II. Development of a Process-Based Alternative

A. The Seeds of an Alternative Approach

The metaphors that were used to illuminate the commons problem and came to be treated as identical with it — the collective action problem and the Prisoner's Dilemma game — led to the conclusion that there was no way out of the commons trap (save for re-organizing the commons as something else). Yet at the same time, those metaphors contained the seeds of another approach.

Our understanding of the collective action problem, as initially elaborated by Mancur Olson and as revisited by Russell Hardin, yielded some important clues as to how certain collective-action situations might differ from one another in ways that made for more promising prospects in some cases than in others. Some of the clues are direct: if collective action is more likely in some cases than in others, perhaps an analogous increase in likelihood of resolution of resource problems might also occur. Some of the clues are indirect, and depend upon our recognizing the <u>differences</u> between a commons situation and a collective-action situation: if a particular characteristic of collective-action situations presents a barrier to successful collective action, and if that same characteristic is <u>not</u> present in commons problems, then perhaps it indicates a greater opportunity for resolving commons problems.

Among the clues from the analysis of collective action are:

(a) the larger the group of potential contributors (or, by analogy, resource users), ceteris paribus, the lower the prospects for successful collective action;

(b) the more concentrated the distribution of interests in the desired good (or the resource), ceteris paribus, the greater the chances for successful collective action, as there may be some individual or some efficacious subgroup capable of producing the desired result;

(c) the greater the extent of other interactions among the members of the group, ceteris paribus, the greater the prospects that they will cooperate in achieving some joint benefit;

(d) because the essence of the public-goods provision problem lies in the inability to exclude non-contributors from receiving benefits (or conversely, the inability to coerce contributions from benefit recipients), we surmise that if users of a common-pool resource are able in some way to exclude others or to compel their behavior, their prospects of successfully managing the resource may improve.

Our understanding of the Prisoner's Dilemma game, from a wide variety of scholars, has also yielded direct and indirect clues concerning the likelihood of obtaining more desirable outcomes. These clues include:

(a) the **greater** the anticipation of future iterations of the sane situation, ceteris paribus, the more likely **players** (or resource users) are to develop strategies that improve on the strategy of consistent non-cooperation;

(b) the more communication allowed between players, ceteris paribus, the greater the likelihood of cooperative actions;

(c) if players are able to make and sustain enforceable threats of sanctions for non-cooperation, ceteris paribus, the likelihood of cooperative action increases

(d) players in a Prisoner's Dilemma game make their choices in isolation from one another; if users of a common-pool resource are able to observe and monitor each other's behavior, this would represent a significant difference between the two situations.

In addition to these deriving from the analysis of collective action problems and Prisoner's Dilemma games, there are some inductive generalizations arising from the set of scholars engaged in direct observation of common-pool cases. Among these are:

(a) where a resource is part of a series of interconnected resources, its location in that series (e.g., "downstream" vs. "upstream") affects the likelihood of the resource users taking action to preserve and manage it, with "downstream" users more likely to act than "upstream" users;

(b) the greater the physical area covered by a resource, ceteris paribus, the less likely it is to be successfully preserved and managed, especially by its users;

(c) the more visible the resource and its boundaries, ceteris paribus, the more likely it is that its users will act to preserve and manage it;

(d) the more stable and homogeneous the group of users, ceteris paribus, the more likely they are to successfully act to preserve and manage the resource;

(e) the more resource information (or at least access to information-gathering facilities) users have, ceteris paribus, the more likely they are to act successfully to preserve and manage the resource;

(f) the greater the degree of real control resource users can have in organizing a resource management system for their situation, ceteris paribus, the more likely they are to act successfully to preserve and manage the resource.

These several clues are the seeds of an alternative approach to the commons in the sense that they suggest that the prospects for a particular commons might not be as bleak

as the "social trap" metaphors and the "inherent logic" reasoning lead one to believe. And if this is so, then resolutions of commons problems may indeed be feasible that do not rely on the imposition of centralized public management or the transformation of the commons into parcels of private property. Moreover, resource users themselves, rather than omniscient regulators, may be the source and engine of the preservation and enhancement of their own common resources. The next step in the development of the alternative approach is the consideration of what such a user-based resolution of a commons problem would entail.

B. The Alternative Approach: Process and Variables

Resolution of a commons problem so as to maintain access for several individuals while keeping aggregate use levels within the capacity of the resource to generate appropriable yields of desirable quality is a complex pursuit. The necessary components of this pursuit can be described briefly as steps in a user-based process (an elaborated, some might say laborious, description is available in Blomquist, 1987: 126-135).

There is no presumption that these steps must be taken either completely privately or completely publicly. Users may in some cases find it to their advantage to avail themselves of existing public capacities, such as expert agencies and courts, and in others to create and control private associations or even to operate with informal private arrangements.

Regardless of the mix of private and public capacities, if they are to develop their own resolution of a commons problem and to achieve optimal use of the resource, users will have to:

(1) develop accurate and sufficiently detailed information about the resource, in order (among other things) to calibrate aggregate use and the total sustainable yield of the resource;

(2) create or adapt some media and form of communication;

(3) establish some collective decision-making mechanism with appropriate boundaries;

(4) adopt a cost-sharing formula;

(5) assign rights of access and use

(6) establish sanctions for non-conforming behavior; and

(7) develop a monitoring mechanism.

It is important to note that this is a fairly "generic" list. There is little presumption of the particular forms and features that these monitoring mechanisms, collective decision-making mechanisms, sanctions, media and fora of communication, etc. will take. There is only the statement that <u>something</u> that counts as a monitoring arrangement, etc. will have to exist. Indeed, based on review of actual commons experiences around the world and across time, we expect variety rather than uniformity in resource-management efforts and techniques.

We also do not anticipate that all users will undertake this process in all endangered resources, nor that users will succeed in completing all of the process everywhere that they begin it, nor that completion of the process

ensures lasting success at resource management. The prospects for initiation of the process, for completion, and for lasting success are in turn conditioned by a set of variables making resolution more or less likely. Those variables, now grouped together as "attributes of the resource", "attributes of the users", and "attributes of institutional capacity", are a compilation of the "seeds" discussed above – characteristics of a resource situation that can affect the chances for successful resource preservation and management. They, too, can be listed briefly below (a more thorough presentation also appears in Blomquist, 1987: 136-153):

<u>Attributes of the Resource:</u>

- rate of renewability of the resource;
- condition of the resource;
- location of the resource (if part of a series);
- size of the resource;
- visibility of the resource;

<u>Attributes of the Users:</u>

- size of the group;
- distribution of interests within the group;
- homogeneity of the group;
- wealth and income of the group;
- extent of other interactions among users;
- stability of the user group and of their use of the resource;
- time horizon of the users;

- availability of an alternative supply for these users of whatever yield they value from the resource;

Attributes of Institutional Capacity:

- degree of real control users can have in designing and implementing resource management;
- availability of facilities for information-gathering;
- ability to make and sustain enforceable agreements;
- presence of an institution with several of the needed capacities.

With the specification of this process and this set of variables, we are in a position to pursue an alternative to the two "solutions" that have prevailed in the literature on the commons. There are two tasks to be pursued in an examination of some common-pool cases in actual settings. First, we seek to establish the possibility that common-pool resources might be preserved, and even enhanced, without resort to either of the forms of solution advanced in the literature. This can be done by identifying a case or cases that have followed neither a centralized public management nor a privatization approach and yet where the "tragedy of the commons" has been overcome. Second, we wish to ascertain the utility of a process-based alternative approach to understanding the resolution of a commons problem. This can be done, though not conclusively, by applying the alternative approach to an examination of some common-pool cases in actual settings and questioning whether it aids in organizing and clarifying our understanding of the processes that occurred in those applications.

III. The Alternative Approach Applied: Four Groundwater Basins in Southern California

A. The Cases

For purposes of exploring the possibility of a user-based resource management system that neither privatizes the resource nor turns it over to some central public manager, and for examining the usefulness of the process-based alternative for organizing our understanding of the resolution of a commons problem, we turn to a selection of four common-pool cases. These cases were quite deliberately chosen. Each is a groundwater basin within the Los Angeles Basin area. This saves us the complications involved in comparing a groundwater basin with a fishery with a forest, and so on. Such cross-resource comparisons are an important part of the agenda for additional research, as we press the alternative views presented here into other areas to explore their general applicability. Choosing all four groundwater basins in the same general location serves a similar simplifying purpose, as it saves comparing California's water problems, water law, and water organizations with those **of some** other state or country, or even comparing southern California's water situation with that of northern California. This keeps the analysis focused on the process and the variables during these comparatively early applications.

No claim is made here that these four groundwater basins are representative examples of all commons situations

wherever in the world they occur. As a result, no inference should be drawn that the analysis of these cases "proves" that all common-pool resources will be saved from overuse and deterioration and devoted to higher-valued use. The cases are too similar and too localized for such sweeping conclusions to be drawn. It is important to underscore that there are also cases consistent with the predictions of traditional approaches, where common resources have been destroyed.

While the cases presented here share a number of similarities, they are not "clones". They differ on some of the variables affecting their situations and in some of the actions taken in the process of resolving their problems. Even with the similarity of resource type and location, there are differences among them that are relevant to the likelihood of collective action, the forms that action took, and the outcomes attained.

The Raymond Basin is a small groundwater basin underlying the Pasadena area in Los Angeles County. It is physically separated from other groundwater basins, and receives its water primarily from runoff of precipitation in the San Gabriel Mountains. Water is removed from the Basin by wells, and is used for residential and commercial purposes in the local communities.

As those communities grew in the first third of the 20th century, water producers began to steadily extract more water than was being restored to the Basin by natural

recharge. Water levels fell, imposing increased costs on water producers (and consumers) through longer pumping lifts required to bring the ground water to the surface. Yet each water producer continued to increase production, thus aggravating the problem of overdraft in the Basin. By the 1930s, Raymond Basin was in critical overdraft condition.

Raymond Basin was not only geographically small; it had a relatively small water production industry as well. There were only about 30 water producers in Raymond Basin in the 1930s. Moreover, that industry was rather concentrated, with the City of Pasadena accounting for as much groundwater production as the other producers combined. The City of Pasadena took the earliest steps to enhance supply through controlled water spreading, and to discuss the demand side of the problem with its fellow producers (to no avail). Subsequently, the City of Pasadena used the California court system to seek an adjudication of rights to the ground water in Raymond Basin. That court case lasted nearly thirteen years, and resulted in a detailed study of the Basin, a negotiated settlement among the water producers, and a reduction of aggregate withdrawals to the total sustainable yield of **the** resource. In the interim, the producers joined with other southern California water producers in securing a supply of imported water from the Colorado River to meet the difference between the needs of the communities and the yield of the Basin.

Initially, the Court appointed a Watenuaster to supervise and monitor the arrangement for the curtailment of demand. More recently, the local water producers have taken over this task, through a representative Management Board. That Board also makes recommendations for adjustments of pumping patterns to optimize use of the storage capacity of the Basin. Water levels in the Basin have recovered and stabilized, periods of drought have been endured, and compliance with the arrangements is sufficiently high that available sanctions have not been enforced against any users.

The West Basin in Los Angeles County covers about four times the area of Raymond Basin. West Basin lays along the Pacific Ocean, underlying the beach cities and stretching from Santa Monica to Long Beach. As a coastal basin, West Basin is the last basin in a series of groundwater basins that begins in the San Gabriel Valley. Also because it is a coastal basin, the underground water-bearing aquifers of West Basin are exposed to the salt waters of the Pacific Ocean for several miles.

In West Basin, overdraft conditions became critical in the early part of this century, and were compounded by the coastal exposure of the Basin. As underground water levels fell below sea level, not only did pumping lifts increase, but salt water from the Pacific invaded the Basin, spoiling the fresh water supply for the beach cities and moving

inland. Moreover, in West Basin, there were hundreds of groundwater producers, rather than a few dozen.

Local water producers pursued five strategies: (l) organizing themselves into a private water association with the ability to seek out information about the Basin and to provide a forum for communication among the members; (2) acquiring an imported supply of water for the Basin that would allow for a future reduction in demands upon the underground supply; (3) using the courts as the Raymond Basin producers had, as a forum for negotiations among the producers leading to a reduction in demand (although, again, the process took sixteen years); (4) developing a mechanism for the increased flow of water into the Basin from the Basins "upstream" through the creation of a Replenishment District that encompassed not only West Basin but the next "upstream" basin, Central Basin; and (5) creation of a barrier project to keep the salt water of the Pacific from further invading the underground water supply. Action in West Basin began in the early 1940s and continued into the 1970s to complete these five elements of the preservation and enhancement of West Basin.

Today, West Basin is no longer in critical overdraft condition, water levels have increased and stabilized, and the salt-water invasion has been arrested. Although most of the water supplied to the West Basin community now is imported, the Basin itself has been preserved as an important source of water supply and as a source of water

storage. The Court-appointed Water-master continues to perform monitoring and reporting functions in West Basin, although compliance with the various arrangements among the local water producers has been unproblematic.

The "upstream" neighbor of West Basin is Central Basin, an even larger resource that stretches from the City of Los Angeles over to Whittier and down to Long Beach. Central Basin receives water from still farther upstream in the San Gabriel Valley, and provides water to West Basin across the fault zone that separates them. As with West Basin, there were hundreds of groundwater producers in Central Basin, providing water for residential, commercial, and agricultural uses.

Water problems reached a critical stage later in Central Basin than they did in Raymond and West Basins. Nonetheless, Central Basin had reached critical overdraft conditions by 1950, and water levels in wells declined sharply. Salt water from the Pacific Ocean even began to intrude into Central Basin in the Long Beach area.

With the assistance of, and some prodding by, downstream producers in West Basin, Central Basin water producers began their own water association to provide a means for information-gathering and dissemination. The Central Basin producers sought to avoid a costly and time-consuming adjudication of rights to withdraw ground water, and managed to accomplish a much briefer and less costly adjudication by employing lessons learned in the course of

the Raymond and West Basin lawsuits. In the meantime, Central Basin producers acquired imported water for the area, and participated in the development of the Central and West Basin Replenishment District, which purchases imported water and reclaimed water for recharge of the Basin's storage capacity. An additional barrier project has arrested salt-water intrusion in the Long Beach vicinity.

Central Basin water levels have recovered, and the Basin is no longer considered endangered by a supply-demand imbalance. The accumulated overdraft in Central Basin has been reduced by one-half. Monitoring of producers' reductions in demand is conducted by the Court-appointed Watermaster in conjunction with the Replenishment District.

Southeast of Central Basin lays the fourth basin in this study, the Orange County Basin. The Orange County basin is slightly larger than the Central Basin, and underlies almost all of the heavily populated areas of the County. At first, water was extracted from the Orange County basin primarily for agricultural irrigation, but most use now is for residential and commercial purposes. The Orange County basin receives water as the last basin in a series in the Santa Ana River valley, and, like West Basin, it is exposed to the Pacific Ocean along the coast.

Because of heavy demand for irrigation, Orange County's basin was overdrafted very early in this century. Water levels receded below sea level, and salt-water intrusion began at two gaps along the shore. Groundwater production

continued to increase, and the problems compounded until the 1950s.

The water producers in Orange County have avoided an adjudication of their rights to withdrawals from the basin, and thus have been unable to place an effective ceiling on water demand. The approach to resource management in Orange County has been to enhance supply to the basin instead of reducing demand. Water producers prevailed upon the California legislature to create the Orange County Water District in the early 1930s. The District has undertaken lawsuits against "upstream" water producers to protect the inflow into the Basin, and a large-scale program of importing and spreading water to recharge the Basin to accommodate the withdrawals of local producers. The District has employed incentive programs to induce producers to substitute imported water for ground water, but has not eliminated the cost differential that makes ground water more attractive than imported water. Barrier projects have been constructed to halt the invasion of salt water from the Pacific.

Water levels fluctuate considerably in Orange County due to **the** absence of a cap on groundwater production, but for most of the period since 1956, the basin has not been in critical overdraft condition. Salt-water intrusion has been contained by the barriers. The continued success of the Orange County approach to resource management depends

largely on the continued availability of imported water for basin replenishment.

These four cases share similarities of resource type and location, but also present different problems in different circumstances. Their histories, and the elements of resource management activity in the four basins, differ. The first important conclusion to be drawn from the cases is that all of them present examples of recovery from "tragedy of the commons" situations, while none of them relied upon the prescribed forms of either total privatization of the resource or management of the resource by a central public agent. What remains is to apply the process-based alternative for understanding such resources and their preservation and management, and to consider the results obtained in each of the cases.

B. The Variables

We have presented a series of variables concerning the resource, the community of users, and the institutional setting, and the relation of these variables to the likelihood of successful resolution. In Figure 1, these variables are reiterated with brief summaries of the status of the four basins with respect to each of the variables.

(Figure 1 here)

A review of the variables readily yields two observations. The four basins were favorably situated for

collective action in a number of respects, and the four basins were quite similar on a number of counts.

Each of the four basins exhibits a low rate of renewability, either because natural recharge is low relative to total basin storage capacity or because the basin is poorly suited to artificial recharge (or, in the case of West Basin, both). This makes each of the basins vulnerable to rapid deterioration under conditions of overuse, yet makes recovery possible if the demand-supply imbalance is redressed (i.e., these are not totally occluded basins where all use takes the form of "mining").

All four basins were in considerably endangered condition prior to and during the process of resolution. This is vital to spur users to undertake the costs of organization and altering use patterns. We would not anticipate that resource users would take actions until they were experiencing problems. While all four basins were endangered, there were differences of degree among them, with West Basin in the most extreme condition of overuse and contamination.

As is the case with groundwater basins generally, the four basins exhibited low visibility. The boundaries of the resources, and thus the extent of the user community, were not readily apparent to the local users. This presents a barrier to successful collective action, and indeed was a prime reason why much of the initial action in each case focused on the gathering of information about the boundaries

of the resource, the capacity and yield of the resource, the conditions of the resource, and the identification of the users. Visibility is one of the variables on which the four basins were not favorably situated for successful collective action. In the case of three of the basins, the usual poor visibility of groundwater basins was compounded by the fact that the acknowledged boundaries of the basins were not all well-defined hydrologic divides.

The number of water producers in all but Raymond Basin was relatively large, but the distribution of interests among the users was concentrated, though to differing degrees. Central Basin was the least concentrated, Raymond Basin the most. Raymond Basin and Orange County each approached the status of "privileged groups," as the City of Pasadena in the former and the Irvine Company in the latter each took actions at the outset despite the fact that their actions ultimately benefitted all users. The concentrated distribution of interests in each case was favorable to collective action, as relatively small groups of users were able to affect large shares of total groundwater production.

Each user community was relatively homogeneous, being undivided by language, culture, or other differences that would impair communication and the possibilities for trust among the users in working out agreements concerning use. Only West Basin exhibited a division among the users, and this was temporary, as the inland cities that were originally unaffected by sea-water intrusion were reluctant

to join with the beach cities in taxing themselves to acquire imported water.

In each basin, there was at the outset of collective action a prosperous community of users capable of bearing costs in addressing their water problems. The development of the Los Angeles area yielded booming cities and a thriving commercial community. That development was itself facilitated by the use of the ground water supplies of the area, and in each of the basins some of the proceeds of that prosperity were able to be redirected to the restoration and preservation of those water supplies.

Each of the basins had a relatively stable community of users with a long time horizon, and with partial networks of interconnection upon which to build more inclusive instruments of collective decision-making. The cities, in particular, were long-term users to whom preservation of a stable and adequate water supply into the future was important. Unlike other types of users, cities are unable to come to an area, exploit its resources, and then pick up and move elsewhere. Similarly, while they are not as immobile as cities, the water service companies, industrial firms, and (in Orange County in particular) large agricultural concerns had considerable stakes in the preservation of an adequate local water supply well into the future. And, within the basins, neighboring cities and neighboring water service companies had extensive other interactions with each other, and industrial and

agricultural concerns had connections with one another through such organizations as area Chambers of Commerce and the Orange County Farm Bureau. The task that remained was to build connections among different types of users, so that cities communicated with industrial producers and water service companies, etc., concerning the problems they all faced. The major users of these basins were neither transients nor total strangers, and this more favorably situated them for successful collective action.

In each of the basins, there became available an alternative, though less preferred, source of water. This made curtailment of demand upon the ground water supply, though costly, less difficult than it would have been otherwise, while underscoring for the local users the value of the less expensive, high-quality, and more stable ground water supplies.

The institutional setting for each of the basins was similar and quite favorable to local collective action. In each basin, users had access to expert information-gathering capabilities, the ability to make and sustain enforceable agreements, the ability to devise local institutions with powers to tax and enforce compliance with whatever arrangements users established, and access to courts where information-gathering, communication, collective decision-making, cost-sharing, share assignments, sanctioning of behavior, and monitoring could occur or be established. Not all of the available capacities were used in each basin,

most notably in Orange County where the use of the courts for intra-basin share assignments was eschewed. The point here is simply that the capacities were indeed available for local users if they chose to incorporate them to facilitate their resolution process.

There were, of course, variables on which the basins differed. Resource location was one of these. Raymond Basin was not directly connected to other basins, and was not exposed to salt-water contamination, and as a result users in that Basin needed only to address their own demand-supply imbalance. Both West Basin and Orange County were located at the extreme downstream ends of their respective watersheds, and were thus highly exposed to the actions of upstream users. Each of these two was also a coastal groundwater basin, highly exposed to salt-water contamination. Central Basin had a more limited exposure to salt-water contamination, being vulnerable in the Alamitos Gap area. Central Basin was also in the position of being both an upstream basin (with respect to West Basin) and a downstream basin with respect to the Upper San Gabriel Valley, and so was also exposed to the actions of upstream users.

The basins also differ in size, from Raymond Basin's 40 square miles to Orange County's 300 square **miles.** The smaller size of Raymond Basin was beneficial to the prospects of successful collective action there, as information-gathering and the other necessary steps in the

resolution process are likely, other things being equal, to be less difficult and costly than they would be when they involve a larger resource.

Raymond Basin also stands out from the others with respect to group size. Each of the other three basins was being used by hundreds of producers prior to and during the period of collective action. In Raymond Basin, where there are only 17 active producers now, there were just 31 fifty years ago at the outset of the Pasadena v. Alhambra litigation. Information-gathering, communication, collective decision-making, and monitoring are each substantially simpler and less costly when total group size is 31 as opposed to 500 or 1,000.

If one were to take the set of variables as a whole, and look across the four basins in an attempt to predict where successful collective action was most likely to occur and where it was most likely to occur first, one could make some tentative observations. Given its favorable disposition with respect to all of the variables except visibility, its clear difference in resource and group size, and a distribution of interests that approached "privileged group" status, one would anticipate collective action to occur first and be most likely to succeed in Raymond Basin. It would be more difficult to predict **a second** most likely case: Orange County had a more favorable distribution of interests, homogeneity of user community, and extent of other interactions of users than West Basin but had a larger

resource, large group of producers, and was in less extreme conditions (at least at first) than West Basin. Central Basin, with its large size, less concentrated distribution of interests, and more limited exposure, would be the basin one would anticipate to be last to exhibit collective action and least likely to be successful, other things being equal. In terms of a strict chronology, the predictions based on the variables alone would be incorrect, as the order of initiation of collective action was in fact Orange, Raymond, West, Central. (Raymond Basin was, however, first to complete the seven steps in the process of resolution.) The variables are not strict conditions, however. They are indicators of likelihood, and the actual course of resolution is a course of human action and not easily subject to deterministic or mechanistic accounts.

C. The Steps in a Process of Resolution

In Chapter Four, the process of resolution of commons problems was described as involving seven steps: information-gathering, communication, collective decision-making, cost-sharing, assignment of shares, establishment of sanctions, and monitoring. Figures 2 through 8 present brief summaries of these seven steps in each of the four basins, focused on the initial (i.e., pre-collective action) condition, the local agents who initiated action with respect to those steps, the other institutional capacities

they engaged in the course of action, and the actions taken and the conditions that prevailed subsequent to action.

(Figures 2 through 8 here)

As with the variables affecting the situations in the four basins, there are considerable similarities and also some differences among the basins. Some points are worth underscoring briefly. First, there was no uniform pattern to the actions taken in the four basins, though they started from similar initial conditions. It cannot be inferred that the initial conditions in the basins "determined" in any meaningful sense the activities therein, as they proceeded along different paths from similar starting places. West and Central Basins come closest to following the same path, which is not surprising in light of their close physical connection and the overlap among the actors there.

Second, in each of the four basins there is a mix of private and public action and leadership, though the mix differs from one basin to another. In Orange County, for instance, collective action originated in private and public arenas, and subsequently the Orange County Water District became the principal locus of activity. By contrast, action in Raymond began primarily in public arenas, and has over time evolved to where the producers' own representative Board has largely taken over management of the Basin. In West Basin, the West Basin Water Association was a principal locus of communication and collective decision-making

before, during, and after the period of most intensive activity.

Of course, the most striking difference among the basins, after review of Figures 2 through 8, is the difference between Orange County and the other three basins. In Orange County, because of the closer relationship of the boundaries and population of the County with the boundaries of the basin, the Orange County Board of Supervisors was more actively involved in local leadership than was the Los Angeles County Board of Supervisors. There was in Orange County much less use, especially with the establishment of the Orange County Water District, of other institutional capacities such as the courts and state agencies than in the other basins.

But it is in the assignment of shares (Figure 6) that the contrast is most stark. In Orange County there has been no assignment of shares to the groundwater supply. The initial condition regarding rights to use of the Orange County basin still prevails today. In the other three basins, firm, tradeable rights based on historical use and limited in aggregate to sustainable levels were established through adjudication. The difference in Orange County does not represent an oversight on the part of water producers there. As noted in Chapter Eight, those who formed the Orange County Water District placed an explicit prohibition upon the District, forbidding it to engage in an intra-basin determination of rights.

This raises an important issue for us, if we propose that a successful resolution would involve action n each of the seven steps. Does the absence of action to assign shares in Orange County mean that Orange County represents an unsuccessful resolution of a commons problem? After all, water levels have recovered from their 1956 lows and sea-water intrusion has been halted in Orange County. In what respects could this be considered unsuccessful? The response to the question lies in the remaining comparisons, on issues of exposure, cost, and efficiency.

D. Comparisons of the Four Basins on Four Criteria

Preserving a valuable resource and organizing its use so as to increase the value it provides for those who rely upon it are substantial achievements. They may, however, be attained in such a way as to make these achievements only temporary and highly vulnerable. Such achievements are also always bought at a price. That price may be measured in terms of the financial costs incurred in the process of resolution, **and** also in terms of the distributional consequences of the management activities. Here, we shall briefly **explore** the actions that have occurred in the four **basins** in **terms** of their continued exposure to depletion and contamination, the financial costs incurred by the users, the comparative benefit of preserving the basins relative to the alternative of destroying and replacing them, and the effect of the basin management programs on the distribution of access and use among the population.

1. Exposure in the Four Basins

Water supply in the Los Angeles area is inadequate and unpredictable. To the extent that the achievements in the four basins have lessened their vulnerability to the inadequacy and unpredictability of water supply, then we can say that a lasting resolution has been attained. Otherwise, temporary improvements have been made that may vanish with the next extended period of drought.

The first form of exposure to consider is loss of supplies. In the Raymond Basin, which is self-contained (being neither an upstream nor a downstream basin), natural local supply is received directly., in the form of runoff from the mountains. Raymond Basin water users can do nothing to regulate the rainfall, but they can attempt to make maximum use of it when it is plentiful. As has been noted, the Basin is poorly suited to artificial replenishment, but various parties in Raymond Basin have operated local spreading grounds in conjunction with the Los Angeles County Flood Control District to capture the natural runoff in the streams that traverse the Basin and allow it to percolate into the underground reservoir rather than flow out of the Basin. This action raises underground water levels during wet periods, which can then be drawn down during dry periods. By restricting total groundwater extractions to the long-term safe yield of the Basin, the Raymond Basin producers have insured that, over long

periods, recharge to the Basin and withdrawals therefrom will be equal, and long dry cycles can be withstood.

In West Basin, the entire source of natural fresh-water replenishment is from Central Basin. The reduction of groundwater withdrawals in Central Basin as a result of the adjudication there, the spreading of local runoff, reclaimed water, and imported water, and the maintenance of a sufficient water level differential between the two Basins have ensured to West Basin a relatively steady supply of fresh water. This supply would be highly expected to the actions of users in Central Basin were it not for the management scheme adopted for the two basins. The fact that the replenishment activities are financed by the Central and West Basin Water Replenishment District gives West Basin producers a voice in decisions regarding their water supply. They also pay to support the supply program even though most of the activity occurs in Central Basin. This fact, combined with the reduction of groundwater extractions in West Basin and the reduction in reliance upon Colorado River water for replenishment, leaves West Basin well able to withstand extended dry cycles.

Central Basin's natural water supply comes from upstream, in the Upper San Gabriel Valley. **The** actions of Central Basin water producers in securing a guaranteed minimum inflow across Whittier Narrows into the Montebello Forebay has markedly reduced their exposure to irregularities in rainfall and to withdrawals upstream. The

inflow from the Upper San Gabriel Valley is supplemented by the spreading of local runoff during wet periods, by the spreading of reclaimed waste water, and by the spreading of imported water from northern California and the Colorado River. The imported water supplies have been the most vulnerable, and the Replenishment District has sought to minimize reliance upon them. With the reduction in groundwater extractions in Central Basin, and with the increase in use of reclaimed waste water, Central Basin is also positioned to withstand the long cycles of dry years that southern California experiences.

Orange County has, like Central Basin, secured for itself a guaranteed minimum inflow from upstream, which has stabilized its ground water supply conditions to some degree. But in Orange County, as we have noted several times, there has been no limitation on groundwater withdrawals. Each year, the Orange County Water District attempts to purchase and spread sufficient amounts of imported water to offset the overdraft caused by groundwater extractions in excess of the basin's safe yield.

Imported replenishment water is the first form of imported water cut back by MWD during dry periods; imported water used for direct service needs receives the higher priority. Orange County water users have not been induced to switch their base supply from ground water to imported direct service water to the degree that users in Central and West Basins (which are similarly situated physically) have

been. Instead, they have relied for most of their total water use on ground water while purchasing replenishment water to make up the overdraft. This has worked so far, for two reasons. First, during the second half of the last extended drought cycle, imported Colorado River water was available in sufficient amounts and at sufficiently low cost to allow the Water District to purchase enough each year to offset the annual overdraft and even to reduce part of the accumulated overdraft. Second, when the availability of imported replenishment water became constrained after California's loss of much of its claimed rights to Colorado River water, the most recent long-term drought cycle abated.

The question that remains for Orange County is what will happen when the next extended drought begins. There is no question that another dry cycle will come. The only question is when it will start because agriculture still represents a larger share of land use in Orange County than it does in the three Los Angeles County basins, Orange County was already more exposed to variability in precipitation, since water demand for agricultural use escalates more rapidly in dry periods than does water demand for residential and commercial uses. With no limitation on groundwater extractions, with ground water being less expensive than imported water for direct service use, and with availability of imported water for replenishment reduced and its cost significantly higher than in the late 1950s and early 1960s, Orange County is highly exposed to

depletion of its ground water supply when the next dry cycle occurs. The current favorable conditions in the Orange County basin must be regarded as transitory and vulnerable.

A second form of exposure to consider is exposure to contamination. This is not a problem in Raymond Basin, which is not exposed to the ocean or to upstream polluters. Any contamination of the groundwater supply in Raymond Basin would come from indigenous pollution sources, and ground water quality is assiduously monitored in this Basin as well as the others for such contaminants. In each of the other basins, the primary threat to ground water quality has been from the ocean, and in each case that threat has been largely eliminated through the construction and operation of the barrier projects. In West and Central Basins, the barrier projects are operated using treated imported water (which is equivalent to direct service water, in priority and in price). In Orange County, the barrier project is operated using purified waste water, which assures a supply of water for the barrier there regardless of precipitation conditions. The Central and West Basin Water Replenishment District is exploring the possibility of using purified waste water in the barrier projects in those basins, thus further ensuring the supply of barrier water in the future.

In all, then, the four basins may be regarded as not exposed to contamination threats (unless pollution problems grow in the future). Three of the four basins may also be regarded as not exposed to the extreme variations in

precipitation that are characteristic of the Los Angeles area. Because of its reliance on imported replenishment water and the absence of assignment of shares to the ground water supply, Orange County remains highly exposed to cyclic fluctuations in local water supply.

2. Basin Management Costs

Basin management costs consist of: watermaster service expenditures (where applicable), water replenishment expenditures (where applicable), and adjudication costs (where applicable). Expenditures cited below are all for 1985, except of course for the adjudication costs, which were incurred earlier.

Arriving at the adjudication costs requires some calculation. Simply to treat all adjudication costs as having been paid in the past and therefore no longer affecting the calculation of basin management costs would not be proper (even though those fees have all long since been paid). It would make for an unfair comparison between Orange County (where the costs of an intra-basin adjudication were avoided) and the other basins. Orange County water users have deliberately avoided this expense, on the theory that "adjudication never produced one drop of water". Their approach should be compared with those where adjudication expenses were incurred in order to see the savings realized by orange County. So, adjudication costs in the other three basins have been included by

amortization. Taking the best estimate available of the total adjudication costs in a basin ($300,000 in Raymond, $3,000,000 in West, and $450,000 in Central), let us engage in the following speculation: suppose the parties had, at the outset of the litigation, borrowed enough money to pay the entire cost of the adjudication up front, and then had made annual payments each year thereafter to pay off the loan. By using a 50-year loan period and a conservative interest rate (reflecting the times in which the money would have been borrowed — 1937, 1945, and 1962) of 5%, we obtain an annual payment for the adjudication that can then be divided by total groundwater extractions to obtain a current cost per acre-foot of ground water resulting from the adjudication of ground water rights within the Raymond, West, and Central Basins.

The resulting basin management costs are summarized in Figure 9. Adjudication costs in Raymond Basin work out to $.50 per acre-foot per year, and watermaster expenditures for 1985 were $3.00 per acre-foot of ground water, yielding a total of $3.50 per acre-foot of ground water. Adjudication costs in West Basin amortize to $2.50 per acre-foot per year, watermaster expenditures were $2.40, and Replenishment District expenditures were $72.50 per acre-foot of ground water, for a total of $77.40 per acre-foot of ground water in West Basin. In Central Basin, adjudication costs are calculated at $.11 per acre-foot per year, watermaster expenditures were $1.16 per acre-foot, and

Replenishment District expenditures were $72.50 per acre-foot, giving a total of $73.79 per acre-foot of ground water. In Orange County, Orange County Water District expenditures were $151.79 per acre-foot of ground water extracted, which is the total basin management costs since there were no adjudication costs or separate watermaster service expenditures (monitoring of groundwater production is also performed by the OCWD).

It would not appear that Orange County water users have saved themselves much money by foregoing assignment of shares. Indeed, the basin management costs in Orange County are substantially higher than they are for the similarly-situated Central and West Basins. By avoiding an intra-basin adjudication putting a ceiling on groundwater extractions, Orange County has had to invest much more heavily in additional spreading facilities to provide enough replenishment capacity to meet the annual overdrafting of the ground water supply, and has had to purchase more imported replenishment water than has CWBWRD, even as the cost of that water has escalated sharply in the first half of this decade. Preservation of the ground water supply in West and Central Basins and Orange County has come at a much higher price than in Raymond Basin. There, the reduction of pumping to the safe yield of the Basin combined with the absence of an artificial replenishment program and the need for a barrier against the sea has kept basin management costs to just $3.50 per acre-foot per year. Basin

preservation has by far come at the highest price in Orange County, where the supply-side approach has necessitated much greater expenditures to accommodate unlimited pumping.

It bears noting that the Orange County basin management costs, stated in "per acre-foot" terms, should not be misread as indicating that groundwater producers pay $151.79 per acre-foot in addition to their direct production costs. If that were the case, Orange County groundwater producers would probably rely upon imported water to a much greater degree than they do. The Orange County Water District still raises a considerable portion of its revenue from property taxes, so property owners still subsidize groundwater production. When District expenditures are divided by total groundwater production, one obtains the $151.79 per acre-foot figure as the cost of basin management per acre-foot produced. But the groundwater producer pays only his direct production costs (estimated at $134.00 per acre-foot) plus the pump tax of $32.00, for a total of $166.00 per acre-foot of groundwater produced, rather than $285.79 per acre-foot, which would be the cost if all basin management costs were paid by taxing groundwater production.

3. Efficiency Considerations

Each year, the Orange County Water District publishes estimates of the direct production costs from pumping ground water, as well as the cost of treated imported MWD water. Assuming for the sake of this presentation that the direct

production costs of extracting an acre-foot of ground water are the same whether the well used is located in Orange County or in Los Angeles County, we can adopt the 1985 estimate of $134.00 per acre-foot for use in considering the savings achieved in the four basins from preserving their ground water supplies relative to total reliance on imported water at $240.00 per acre-foot.

A groundwater basin can be used in more than one way. The water supplied by the basin can be used to meet the base supply needs of the users, or the basin can be used as a storage facility to provide water for peak and emergency use while base supply needs are met from surface and imported supplies. Given the growth in total water use in each of the four basins, if the water users had pursued the first of these methods, each of the four basins would have been destroyed by now, by depletion or by contamination or both. Had this occurred, the provision of a water supply to the population and commerce of these areas would now require use of imported direct service water to meet 100 percent of total water use. However, because of the variability of supply of imported water (i.e., there are wet and dry seasons within each year and there are wet and dry years), and because of the variability of demand for water (i.e., water needs at the peak hour of the peak day of the peak season may be as much as twenty times the average rate of use), considerable investment would have to be made in storage facilities to replace those provided naturally by

the groundwater basins. In order to evaluate whether the price that has been paid for preservation of the groundwater basins has been worth it to the local users, we need to find some way of estimating the costs they would be incurring for their water supply if they had allowed the basins to be destroyed.

In order not to overstate the case, we will proceed as follows. We will take the lowest estimate found of the amount of surface storage capacity required to make up for the loss of the underground system. This is an estimate that storage facilities would have to be constructed equivalent to 16 percent of total water use. We will then use the lowest estimate available of the capital cost of constructing that amount of surface storage in each of the basins, $57,440 per acre-foot. We then amortize this construction at 5% per year over a 50-year period, as was done with adjudication costs earlier, to obtain an annual cost of the construction of the required surface storage. Finally, we include no cost for annual maintenance of these surface storage facilities — i.e., we will assume that they never **need** cleaning, repainting, or repairs, thus treating them as equivalent to natural underground storage.

The results of these calculations are presented in Figure 9. We will work through the calculations for Raymond Basin as an example of how the calculations were performed for all four basins. In Raymond Basin, where the current mix of ground water and imported water is 54% to 46%,

calculating ground water at $134.00 per acre-foot plus the $3.50 basin management costs and imported water at $240.00 per acre-foot, an average acre-foot of water costs $184.65. If Raymond Basin water users were totally reliant on imported water, they would require 8,571 acre-feet of storage capacity (.16 times total water use of 53,567 acre-feet), which at $57,440 per acre-foot would cost $492,318,240.00. Annual payments for this construction would be $27,248,400.00, or $508.68 per acre-foot of water used. Adding this to the $240.00 per acre-foot cost of imported direct service water yields a total of $748.68 per acre-foot of water in Raymond Basin. Since an acre-foot of water is the average annual demand for a five-person household, we can translate this difference between $184.65 per acre-foot under the current system and $748.68 per acre-foot under the alternative as the difference between an average monthly water bill of $15.00 and an average monthly water bill of $62.50. The alternative costs of water for each of the other basins can also be seen in Figure 9.

Even with conservative estimates of the cost of replacing the groundwater basins in this study with surface storage and imported water, it appears that basin preservation has been a good bargain. We are unable to make efficiency determinations of the type that would indicate whether basin management costs are as low as they can possibly be in each of these basins, and there is no reason to presume that they are, but we can conclude that the basin

management costs being paid in each of the basins are considerably less than the costs the water users in these areas would be facing if the basins had been destroyed.

4. Distributional Considerations

In each of the basins there has been a reduction in the number of entities producing ground water. The question now becomes how to evaluate this phenomenon.

There is no doubt that in West and Central Basins, the adjudication process itself eliminated many of the small producers. They abandoned groundwater production rather than pay the costs of defending their right to a few acre-feet or less of ground water. This occurred despite the fact that the ground water industry in each of these two basins was sufficiently concentrated that a smaller group of large producers could have curtailed their use and preserved the basins by their own actions. The impact of the production by the very small producers on aggregate groundwater extractions would have been minimal. Yet in the adjudications of those basins, the parties sought to spread the costs over the total set of producers, even though this resulted in the elimination of most of them from production. Those **small** producers, had they not been eliminated, could today still be pumping their one or two acre-feet per year and enjoying the lower cost and high quality of the ground water instead of having to acquire imported water.

There are, however, other considerations that counsel caution in attributing all of the reduction in the number of

small pumpers to the adjudication process. Some small pumpers were agricultural producers. As land use in the area has changed from agricultural to residential and commercial, several of these producers sold their farmland to real estate developers, and so would not have been pumping ground water anymore regardless of the onset of adjudication.

In Orange County, where there has been no intra-basin adjudication of rights, many more small producers have continued production of ground water. Given the physical similarity of Orange County with Central and West Basins, it is therefore reasonable to suppose that many more small producers would also have continued production in those basins had it not been for adjudication (although it should be reiterated that irrigated agriculture represents a larger share of land use in Orange County, so again, not all of the differences can be attributed solely to adjudication). This discussion does not relate as strongly to Raymond Basin, as the ground water industry there was small to begin with and remains so, and during the process of adjudication itself the number of parties declined only from 31 to 25.

If the criterion one uses to evaluate the distributional consequences of the actions in the various basins is the effect on the small vs. large producers, one would therefore conclude that Orange County's approach has been considerably more equitable than that of West and Central Basins. Small producers have not been chased out of

the ground water industry in Orange County, and continue to derive substantial benefits from being able to produce their own water from underground rather than having to purchase it from others.

However, there is another aspect to distribution. In addition to the issue of whether the large producers could have suffered the small producers to continue production (which they surely could have) by omitting them from the assignment of shares, there is the issue of whether the value of rights to groundwater production has been appropriately reflected in the various basins. In Orange County, the absence of an assignment of shares to the groundwater supply means that there are no tradable groundwater rights in Orange County — rights remain usufructory and hence untradable. Small producers thus continue to produce, but we cannot be sure whether they do so because they prefer their groundwater rights to whatever compensation they could receive for them or because they simply have no other option but to use their right to produce as opposed to buying water from another source.

In Raymond, West, and Central Basins, there has been further reduction in the number of parties owning rights since the end of the adjudication process in each of those basins. In other words, parties who went through the adjudication process, paid the costs thereof, and acquired decreed rights to groundwater production nonetheless have disposed of their rights subsequently. In Raymond Basin,

the 25 parties who completed the adjudication process are now 17. In West Basin, 99 parties were decreed to have non-zero rights in 1961; now there are 74, of whom only 37 are active pumpers (the rest lease their rights to the 37). In Central Basin, there were 508 parties with pumping allocations in the first year after the judgment; there are 184 now, of whom 116 are active pumpers. In these basins, parties with rights have four options: (a) exercise their rights to pump in full; (b) sell their rights in full and become water consumers instead of water producers; (c) retain their rights for future use but lease them to another for current use; and (d) some combination of the other three options — i.e., pump some, sell some, lease some.

This other aspect of distribution, then, is whether rights to ground water are possessed by those who most value them. In Raymond, West, and Central Basins, we cannot presume that the market for water rights works perfectly. We cannot therefore conclude that groundwater rights are entirely in the hands of those who most value them. We can, however, at least observe that the capacity exists for those who value their water rights less than others to exchange them with those others for something they value sore. We are then able to infer that, when a water right owner ceases production and transfers his right to another, he has made a judgment about the resolve value of his right and has received some form of sensation for it that he deems acceptable.

By contrast, in Orange County, when a groundwater producer ceases production and becomes a water consumer rather than a water producer, it is much less clear what we are to make of that action. The number of ground water producers pumping 25 acre-feet per year or less in Orange County has declined from 780 in 1970 to 250 in 1985. All that we can say of the 530 small producers who have given up ground water production in those 15 years is (a) that they did not continue their groundwater production, and (b) that they received no compensation when they ceased that production.

Our conclusions, then, are mixed on the issue of the distributional consequences of the actions taken in the four basins. The process of adjudication undoubtedly eliminated several small producers from access to and use of the basins (especially West and Central), even though they could have been excluded from that process. The absence of an adjudication process in Orange County likely accounts for the continued presence of 250 relatively small ground water producers there. However, had the small producers in West and Central Basins been omitted from the adjudication of rights, they would also have ended up with no firm, tradable shares that they could exchange with others who valued them more. In Orange County, there is no way to determine that groundwater production is being pursued by those who value it most; one can only say that groundwater production is pursued by those who value it more than not producing. In

the other basins, there is at least the possibility that rights to groundwater production have moved from those who valued them less to those who valued them more.

IV. Summary: Getting Out of the Commons Trap

These cases demonstrate quite plainly that common-pool resources (a) do not have to be destroyed simply because multiple individuals or firms have claims to their use, (b) do not have to be converted from common property arrangements to some other form of property arrangements in order for destruction to be averted, and (c) do not have to be managed by a central government manager or converted to individually-held private property in order to be devoted to a higher-valued use. Despite the fact that no claim is made for their representativeness, these cases do at least show that it is possible for commons problems to be resolved by the users themselves. They refute each of the alternative contentions in the literature, i.e., that overall governmental control is "required", or that privatization of natural resources is "the only way", to ensure optimal use. The cases also support the recommendation of the National Academy of Sciences Panel on Common Property Resource Management that policymakers should first investigate whether management arrangements have been established by local users before the imposition of one of the "package" solutions of the literature on commons situations.

In addition, these cases appear to support the utility of a process-based alternative approach to the understanding of the resolution of commons problems. The seven-step process illuminates not only the elements of user-based resource management, but also helps in identifying potential weaknesses in a resource management system (as with Orange County's choice of foregoing assignment of shares). In a simple case comparison, the identification of a set of variables making resolution more or less likely aids in our understanding of the prospects for initiation and the prospects for successful completion of collective action among the users in the four cases. There would appear to be reason for further pursuit of this approach, for its usefulness for analysts of common-pool resource situations, and for its usefulness as a guide to action for resource users seeking a way out of the commons "trap".

FIGURE 1

Comparison of the Variables in the Four Basins

Variable	Raymond Basin	West Basin	Central Basin	Orange County
Rate of Renewability of the Resource	Low-- Small Capacity; Safe Yield 31,000 acre-feet; poorly suited for artificial recharge	Low-- Large Capacity; Safe Yield 36,000 acre-feet; poorly suited for artificial recharge	Low-- Large Capacity; Safe Yield 157,000 acre-feet; well suited for artificial recharge	Low-- Large Capacity; Safe Yield 150,000 acre-feet; well suited for artificial recharge
Condition of the Resource	Overdraft began 1913; Annual overdraft, 1913-35, 7,000 af.; 1936-43, 8,500 af. Water levels dropped 30-50 ft. 1930-37 No salt-water intrusion.	Overdraft began 1920; Annual overdraft, in 1920s, 20,000 af.; in 1930s, 25,000 af.; in 1940s, 40,000 af.; 1950-53, 60,000 af. Water levels in Hawthorne area down 200 feet; Accum. overdraft, 832,000 acre-feet in 1957; 400,000 acre-feet of salt water came in, 1932-53	Overdraft began 1942; Annual overdraft, in 1950, 77,000 af.; in 1960, 149,000 Water levels dropped 100 feet; Accum. overdraft, 1.3 million acre-feet in 1960; Salt-water intrusion 2 miles inland of Uplift	Overdraft began by 1920; Annual overdraft, nearly 100,000 af. by 1950; average water level below sea level by 1949; Accum. overdraft, 500,000-700,000 acre-feet in 1956; Salt-water intrusion 3 1/2 miles inland

Figure 1 (cont'd)

Variable	Raymond Basin	West Basin	Central Basin	Orange County
Location of the Resource	Self-contained; not exposed to salt-water contamination	Extreme downstream; highly exposed to salt-water contamination	Upstream and downstream; limited exposure to salt-water contamination	Extreme downstream; highly exposed to salt-water contamination
Size of the Resource	Small--40 sq.mi.	Larger--170 sq.mi.	Large--277 sq.mi.	Large--300 sq.mi.
Visibility of the Resource	Poor--as with all ground water basins	Poor--with unclear bounds at north & south ends	Poor--with unclear bounds at north & south ends	Poor--with unclear bounds at west end
Size of the Group	Small--31 in 1937, 17 now	Large--over 700 well owners, 491 parties and 279 active producers in 1950, 37 active pumpers now	Large--750 well owners, 508 parties; with rights in 1967, 187 now	Large--over 1,000 producers as late as 1970, over 300 now
Distribution of Interests	Nearly privileged as City of Pasadena accounted for half of total production	Concentrated industry: in 1950, 19 parties accounted for 84% of total production	Concentrated industry: in 1950, 17 parties accounted for half of total production	Concentrated industry: cities, large agricultural holdings, water service companies; Irvine Ranch especially significant

Figure 1 (cont'd)

Variable	Raymond Basin	West Basin	Central Basin	Orange County
Homogeneity of the Group	No salient cleavages	Division between inland and beach cities; no other salient cleavages	No salient cleavages	No salient cleavages
Wealth and Income of the Group	Prosperous community: cities & major private producers had funds & personnel to devote to process	Prosperous community: cities & major private producers had funds & personnel to devote to process	Prosperous community: cities & major private producers had funds & personnel to devote to process	Prosperous community: cities & major private producers had funds & personnel to devote to process
Extent of Other Inter-actions Among Users	Cities had contacts with each other; water service companies did also	Cities had contacts with each other; water service companies did also; industrial users also	Cities had contacts with each other; water service companies did also; industrial users also	Cities had contacts with each other; water service companies did also; industrial & agricultural users also
Stability of Group and Use	Group of producers remained stable; use grew steadily	Group of producers stabilized after WWII; use grew rapidly until 1950s	Group of producers stabilized after WWII; use grew rapidly until 1960s	Group of producers stabilized after WWII; use grew rapidly until 1970s

Figure 1 (cont'd)

Variable	Raymond Basin	West Basin	Central Basin	Orange County
Time Horizon of Users	Cities & water service companies committed to area and basin use indefinitely	Cities & water service companies committed to area and basin use indefinitely; industrial users had large capital investments to protect	Cities & water service companies committed to area and basin use indefinitely; industrial users had large capital investments to protect	Cities & water service companies committed to area and basin use indefinitely; industrial users had large capital investments to protect
Availability of an Alternative Supply	Yes, through MWD, but costs higher & quality poorer	Yes, through MWD, but costs higher & quality poorer	Yes, through MWD, but costs higher & quality poorer	Yes, through MWD, but costs higher & quality poorer
Degree of Real Control Users Can Have	Home rule; State accomodating of local control; access to courts; ability to establish limited-purpose special districts	Home rule; State accomodating of local control; access to courts; ability to establish limited-purpose special districts	Home rule; State accomodating of local control; access to courts; ability to establish limited-purpose special districts	Home rule; State accomodating of local control; access to courts; ability to establish limited-purpose special districts

Figure 1 (cont'd)

Variable	Raymond Basin	West Basin	Central Basin	Orange County
Availability of Information-Gathering Facilities	Extensive: Courts, State Agencies, USGS Surveys, Local Agencies (e.g., LACFCD Engineers)	Extensive: Courts, State Agencies, USGS Surveys, Local Agencies (e.g., LACFCD Engineers)	Extensive: Courts, State Agencies, USGS Surveys, Local Agencies (e.g.. LACFCD Engineers)	Extensive: Courts, State Agencies, USGS Surveys Local Agencies (e.g.. OCFCD Engineers)
Ability to Make and Sustain Enforceable Agreements	Yes-- Common-law tradition; Civil court procedures	Yes-- Common-law tradition; Civil court procedures	Yes-- Common-law tradition; Civil court procedures	Yes-- Common-law tradition; Civil court procedures
Presence of a Single Institution With Several Needed Capacities	Yes-- courts	Yes-- courts	Yes-- courts	Yes-- courts

FIGURE 2

Step One: Information-Gathering

	Raymond Basin	West Basin	Central Basin	Orange County
Initial Condition	Boundaries and Users Unknown; Users know only their own use & water levels	Boundaries and Users Unknown; Users know only their own use & water levels	Boundaries and Users Unknown; Users know only their own use & water levels	Boundaries and Users Unknown; Users know only their own use & water levels
Local Leadership	City of Pasadena	West Basin Survey Committee; West Basin Conserva-tion Group; LACFCD	Central Basin Water Ass'n.	Orange County Board of Supervisors
Other Capacities Engaged	USGS, DWR as Referee	USGS, • • DWR as Referee	SWRB	
Actions Taken and Subsequent Conditions	Lawsuit yields analysis. of Basin conditions and use patterns; after suit, Uatermaster Reports continually apprise users of Basin conditions and use patterns	Early actions of local users provide shared picture of Basin and its dangers; lawsuit yields analysis of Basin conditions and use patterns; annual Watermaster Reports thereafter	SWRB Report shows that Basin is in worse condition than supposed; CWBWRD compiles histories of use prior to lawsuit; after suit, Watermaster Reports update Basin conditions and use	County Supervisors commission Lippincott Report indicating severity of Basin problems; after 1953, annual Engineer's Reports update Basin conditions and give some use data

FIGURE 3

Step Two: Communication

	Raymond Basin	West Basin	Central Basin	Orange County
Initial Condition	Cities & water service companies had contact	Cities & water service companies had contact	Cities & water service companies had contact	Informal network of local govt's and trade associations
Local Leadership	Pasadena intiated meetings & lawsuit	LACFCD & City of Manhattan Beach initiated meetings	Compton intiated meetings leading to CBWA	Farm Bureau, Chambers of Commerce, County Board of Supervisors
Other Capacities Engaged	Court	Court	Court	
Actions Taken and Subsequent Conditions	Lawsuit prompted negotia-tion among parties, leading to formation of Raymond Basin Advisory Board, which becomes Management Board	West Basin Survey Committee becomes West Basin Water Association which is permanent forum for discussion of Basin problems & possible actions; Settlement Committee organizes negotiated reduction in pumping	Central Basin Water Association serves as permanent forum for discussion of Basin problems & possible actions; Settlement Committee organizes negotiated reduction in pumping	OCWD formed with represen-tation by area, becomes focus of information gathering and dissemination

FIGURE 4

Step Three: Collective Decision-Making

	Raymond Basin	West Basin	Central Basin	Orange County
Initial Condition	No collective decision-making mechanism	No collective decision-making mechanism	No collective decision-making mechanism	Orange County Board of Supervisors, but it does not match Basin boundaries
Local Leadership	City of Pasadena initiates lawsuit	Cities & major companies form WBWA	Cities & major companies form CBWA	County Board & Farm Bureau, Irvine Ranch
Other Capacities Engaged	Court	Court	Court	
Actions Taken and Subsequent Condition	Through lawsuit, pumpers negotiate reductions in pumping which are approved by Court; afterward, Raymond Basin Management Board becomes decision-making mechanism for the Basin	WBWA aids in conduct of lawsuit, and then organizes CWBWRD. Reduction in pumping and ways of replen-ishing Basin & halting sea-water intrusion along with CWBWRD. Much inter-agency decision-making-- e.g., WBWA with CWBWRD, LACFCD, WBMWD, MWD, etc.	CBWA organizes CWBWRD, which conducts lawsuit resulting in pumping reduction. CBWA also serves as mechanism for making decisions about recharge & barriers along with CWBWRD. Much inter-agency decision-making -- e.g., CBWA with CWBWRD, LACFCD, CBMWD, MWD, etc.	Through Irvine Ranch lawsuit, OCWD is formed as agency through which decisions about basin management are made

FIGURE 5

Step Four: Cost-Sharing Arrangements

	Raymond Basin	West Basin	Central Basin	Orange County
Initial Condition	Producers pay only direct production costs; actions benefitting the Basin paid by the actor	Producers pay only direct production costs; actions benefitting the Basin paid by the actor	Producers pay only direct production costs; actions benefitting the Basin paid by the actor	Producers pay only direct production costs; actions benefitting the Basin paid by the actor
Local Leadership	City of Pasadena initiated lawsuit	Cities form WB Survey Committee & later org's.	17 original CBWA members	County Board & Farm Bureau
Other Capacities Engaged	Court	Court, Legislature & County Board	Court, Legislature & County Board	State Legislature
Actions Taken and Subsequent Conditions	During lawsuit, Court apportioned costs on basis of pumping rights; this becomes basis for support for Watermaster Service & Management Board	Within WBWA, dues assessed on ground water production and this formula is used to pay for CWBWRD programs; property tax used for early recharge & barrier programs & to make up accum. overdraft	Within CBWA, dues assessed on ground water production and this formula is used to pay for CWBWRD programs; property tax used for early recharge & barrier programs & to make up accum. overdraft	Early OCWD formed to spread costs of Irvine litigation through property tax; later, this tax is supplemented by tax on ground water production to pay for artificial recharge & barrier programs

FIGURE 6

Step Five: Assignment of Shares

	Raymond Basin	West Basin	Central Basin	Orange County
Initial Condition	Rights to unlimited production through ownership of land; rights to specific amounts through use	Rights to unlimited production through ownership of land; rights to specific amounts through use	Rights to unlimited production through ownership of land; rights to specific amounts through use	Rights to unlimited production through ownership of land; rights to specific amounts through use
Local Leadership	City of Pasadena	Plaintiffs in suit, WBWA	CWBWRD & CBWA	
Other Capacities Engaged	Court, DWR as Referee	Court, DWR as Referee	Court	
Actions Taken and Subsequent Conditions	Through stipulation of parties based on DWR study, and "mutual prescription", rights to ground water production defined based on historical use, separated from land ownership, and made tradeable	Through stipulation of parties based on DWR study and "mutual prescription", rights to ground water production defined based on historical use, separated from land ownership, and made tradeable	Through stipulation of parties and "mutual prescription", rights to ground water production defined based on historical use, separated from land ownership, and made tradeable	OCUD forbidden from acting to define rights to ground water among Orange County producers; initial conditions prevail

FIGURE 7

Step Six: Establishment of Sanctions

	Raymond Basin	West Basin	Central Basin	Orange County
Initial Condition	No sanctions	No sanctions	No sanctions	No sanctions
Local Leadership	City of Pasadena	Plaintiffs in suit, WBWA, CWBWRD	CBWA, CWBWRD	OCWD Board
Other Capacities Engaged	Court, State Legislature, DWR as Watermaster	Court, State Legislature, DWR as Watermaster	Court, State Legislature. DWR as Watermaster	State Legislature
Actions Taken and Subsequent Conditions	Production in excess of right results in fine & possible loss of right; failure to report production results in fine & possible loss of right; failure to pay pump tax can result in fine & possible imprisonment	Production in excess of right results in fine & possible loss of right; failure to report production results in fine & possible loss of right; failure to pay pump tax can result in fine & possible inprisonment	Production in excess of right results in fine & possible loss of right; failure to report production results in fine & possible loss of right; failure to pay pump tax can result in fine & possible imprisonment	Failure to report production results in fine & possible imprisonment; failure to pay pump tax results in possible fine & possible imprisonment; production in excess of basin production percentage by covered producers subjects them to basin equity assessment

FIGURE 8

Step Seven: Monitoring

	Raymond Basin	West Basin	Central Basin	Orange County
Initial Condition	No monitoring	No monitoring	No monitoring	No monitoring
Local Leadership	City of Pasadena	WBWA Settlement Committee	CBWA Settlement Committee	OCWD Board
Other Capacities Engaged	Court, State Legis-lature, DWR	Court, State Legis-lature, DWR	Court, State Legis-lature DWR	State Legislature
Actions Taken and Subsequent Conditions	Court, adopting parties' agreement, appoints DWR as Watermaster to monitor parties' production	Court, adopting parties' agreement, appoints DWR as Watermaster to monitor parties' production, CWBWRD also monitors in order to assess pump tax	Court, adopting parties' agreement, appoints DWR as Watermaster to monitor parties' production, CWBWRD also monitors in order to assess pump tax	Amendments to OCWD Act require reporting of ground water production, annual Engineer's Reports

FIGURE 9

Basin Management Costs and Savings per Acre-Foot from Basin Management in the Four Basins

	Raymond Basin	West Basin	Central Basin	Orange County
Basin Management Costs per Acre-Foot of Groundwater Extractions, 1985	$ 3.50	$ 77.40	$ 73.77	$ 151.79
Average Cost of an Acre-Foot of Water With Basin Management	$ 184.65	$ 235.71	$ 224.85	$ 267.93
Estimated Cost of an Acre-Foot of Water if All Ground Water Replaced by Imported Water	$ 748.68	$ 739.30	$ 739.94	$ 740.21

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